REVIEW ON THE PARASITIC HELMINTHS OBTAINED FROM FIVE SEABIRD SPECIES KILLED IN "NAKHODKA" OIL SPILL WITH SOME RELATED INFORMATIONS

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ABSTRACT

Large numbers of seabirds were killed or injured in the "Nakhodka" oil spill in the Sea of Japan on 2 January 1997. More than one thousand dead or living seabirds were collected for rescue and scientific research along the oil-fouled on many beaches. Many of the dead birds were examined for parasitic helminths. Two trematode, one cestode, and six nematode species were obtained. An echinostomatid trematode, *Aporchis* sp., was found in the intestine of 10 of 166 ancient murrelets (*Synthliboramphus antiquus* (Gmelin, 1789)) and 1 of 37 rhinoceros auklets (*Cerorhinca monocerata* (Pallas, 1811)). A renicolid trematode, *Renicola* sp., was found in the kidney of 21 of 50 ancient murrelets and 15 of 50 rhinoceros auklets. An anisakid nematode, *Contracaecum rudolphii* Hartwich, 1964, was found in the intestine of 73 of 166 ancient murrelets, 2 of 3 marbled murrelets (*Brachyramphus marmoratus* (Gmelin, 1789)), 9 of 37 rhinoceros auklets, 6 of 12 Pacific loons (*Gavia pacifica* (Lawrence, 1858)), and 2 of 14 red-necked grebes (*Podiceps grisegena* (Boddaert, 1783)). Three species of acuariid nematodes were found in the gizzards: *Paracuaria adunca* (Creplin, 1846) in 5 of 43 ancient murrelets; *Stegophorus stercorarii* Leonov, Sergeeva & Tsimbalyuk, 1966 in 9 of 43 ancient murrelets; and *Streptocara crassicauda* (Creplin, 1829) in 1 of 19 rhinoceros auklets and 1 of

12 Pacific loons. Other helminths found were: Cestoda fam. gen. sp. in the intestine of 1 of 37 rhinoceros auklets; a syngamid nematode, *Syngamus* sp., in the intestine of 1 of 37 rhinoceros auklets; and a trichurid nematode, Capillariinae gen. sp., in the gizzard of 1 of 12 pacific loons. The parasitic helminth community was simpler in the red-necked grebe than in the other four examined bird species. This may be attributable to the short history of adaptation to the marine environment of this host bird species.

INTRODUCTION

Large numbers of seabirds were killed or injured in the "Nakhodka" oil spill in the Sea of Japan on 2 January, 1997. At least 1315 dead or living seabirds were collected for rescue and scientific research along the oil-fouled beaches (Mizutani, 1997). I have investigated the parasitic helminth faunas of five species of those dead seabirds with my collaborators (Yokohata, 2002). Some host species, such as gulls and cormorants, will be researched in the near future. In this paper, I show the results of our investigation obtained till now and discuss the parasitic helminth faunas of the five seabird species with other related informations, such as on the host ranges of the helminth species and the epidemiological aspects of them.

SEABIRDS EXAMINED IN OUR INVESTIGATION

At the "Nakhodka" oil spill, more than 450 ancient murrelets (*Synthliboramphus antiquus* (Gmelin, 1789)), ca. 500 rhinoceros auklets (*Cerrorhinca monocerata* (Pallas, 1811)) and ca. 20 individuals of other species of alcids were recovered. They took the most part of the recovered oiled birds, and some species of loons, grebes, gulls, etc. were included in the rest oiled birds (Mizutani, 1997). Also in our investigation, the alcids were the host group in which the most number of individuals was examined. The digestive tracts of 166 ancient murrelets and three marbled murrelets (*Bradyramphus marmoratus* (Gmelin, 1789)) from Ishikawa Prefecture and those of 37 rhinoceros auklets from Yamagata (9 birds), Niigata (10) and Fukui (4) Prefectures and from unknown locality (14). Other than these alcids, the digestive tracts of 12 Pacific loons (*Gavia pacifica* (Lawrence, 1858)) and 14 red-necked grebes (*Podiceps gricegena* (Boddaert, 1783)) were examined.

Among these seabird species, there are remarkable differences on the amount of existing reports of parasitological studies. For example, Some grebes including the red-necked grebes have been studied relatively well (e.g., Stock and Holmes, 1987, 1988), whether reports on parasites of ancient murrelets are very few (Gaston, 1994).

METHODS OF PARASITOLOGICAL EXAMINATION

Pathological examination of the seabirds were performed in Laboratory of Veterinary Pathology, Faculty of Agriculture, Gifu University, Japan and Wildlife Rescue Veterinarian Association, in Tachikawa, Japan, and histological sections of the kidney of each 50 ancient murrelets and rhinoceros auklets were observed to detect parasitic helminths. The digestive tracts of the seabirds were fixed in formalin solution at the pathological examination, transported to our laboratory and dissected under zoom stereoscopic microscopes. Helminths obtained were refixed in 70 % ethanol solution, stained with aceto-carmine solution (trematodes and cestodes) or cleared with lacto-phenol solution (nematodes), and microscopically examined (Yokohata, 2002).

TREMATODES

In our study, two species of digenetic trematodes (Platyhelminths: Trematoda: Digenea) were so far obtained (Yokohata, 2002; Table 1).

(1) *Aporchis* sp. (*Aporchis* cf. *rugosus* Linton, 1928)

We found many trematodes with long, slender bodies and many collar spines from intestines of ten ancient murrelets and one rhinoceros auklet (probably accidental). The worms were belonging to the genus *Aporchis* (Echinostomida: Echinostomatidae), and similar to *A. rugosus* Linton 1928, which were discovered from an arctic tern (*Sterna paradisaea* Pontopiddan, 1763). But Linton (1928) lacked description of number and shape of their collar spines, probably due to defection, so that we could not compared our specimens with this species precisely. In Table 2, I show the hosts and localities of existing eight species of this genus. Each species has apparently specialized to its hosts in the generic level of them, although not vice versa. This fact may suggest that the present *Aporchis* sp. is not *A. rugosus*, but it is difficult to

Table 1 Parasitic helminths obtained from seabirds along oil-fouled beaches of the Sea of Japan (Yokohata, 2002).

Host species／Helminth species (Groups)	Number of hosts Infected／examined	Total no. of worms obtained	Locality (Prefectures)
Ancient murrelets *Synthliboramphus antiquus*			
Aporchis sp. (T)	10／166	23	Ishikawa
Renicola sp. (T)	21／50*	unknown**	Ishikawa, etc.*
Contracaecum rudolphii (N)	73／166	numerous	Ishikawa
Paracuaria adunca (N)	5／43	8	Ishikawa
Stegophorus stercorarii (N)	9／43	10	Ishikawa
Marbled murrelets *Bradyramphus marmoratus*			
Contracaecum rudolphii (N)	2／3	3	Ishikawa
Rhinoceros auklets *Cerrorhinca monocerata*			
Aporchis sp. (T)	1／37	1	Niigata
Renicola sp. (T)	15／50	unknown**	Ishikawa, etc*
Cestoda fam. gen. sp. (C)	1／37	1	Niigata
Contracaecum rudolphii (N)	9／37	24	Yamagata to Fukui
Streptocara crassicauda (N)	1／19	3	Niigata
Syngamus sp. (N)	1／37	1	Niigata
Pacific loons *Gavia pacifica*			
Contracaecum rudolphii (N)	6／12	46	Akita to Shimane
Streptocara crassicauda (N)	1／12	1	Hyogo
Capillarinae gen. sp. (N)	1／12	2	Tottori
Red-necked grebes *Podiceps gricegena*			
Contracaecum rudolphii (N)	2／14	3	Ishikawa and Fukui

Groups: T: Trematoda; C: Cestoda; N: Nematoda; *personal communication from Dr. T. Masegi; **observed only in histopathological sections.

Table 2 Hosts and localities of existing eight species of the genus *Aporchis*

Species	Hosts	Localities
A. croaticus	European shag *Carbo* (=*Phalacrocarax*) *graculus*	Fiume, Yugoslavia
A. segmentatus	Swift tern *Sterna* (= *Thalasseus*) *bergii*	Yate, New Caledonia
A. rugosus	Arctic tern *S. paradisaea*	Woods Hole, Massachusetts, USA
A. liouvillei	Herring gull *Larus argentatus*	Mogador, Morocco
A. massiliensis	Herring gull *L. argentatus*	Riou Island, France
A. continuus	Common gull *L. canus*, Glaucous-winged gull *L. glaucescens*, Black-legged Kittiwake *L. tridactylus*	Columbia River, Oregon, USA
A. lari	Bittern *Botaurus stellaris*	Uzbekisan, USSR
A. mozambiquus	Ruddu turnstone *Arenaria interpres*	Mozambique

Based on Linton (1928), Timon-David (1955), McCauley and Pratt (1960), Sultanov (1961), Deblock (1966) and Hoberg (1981).

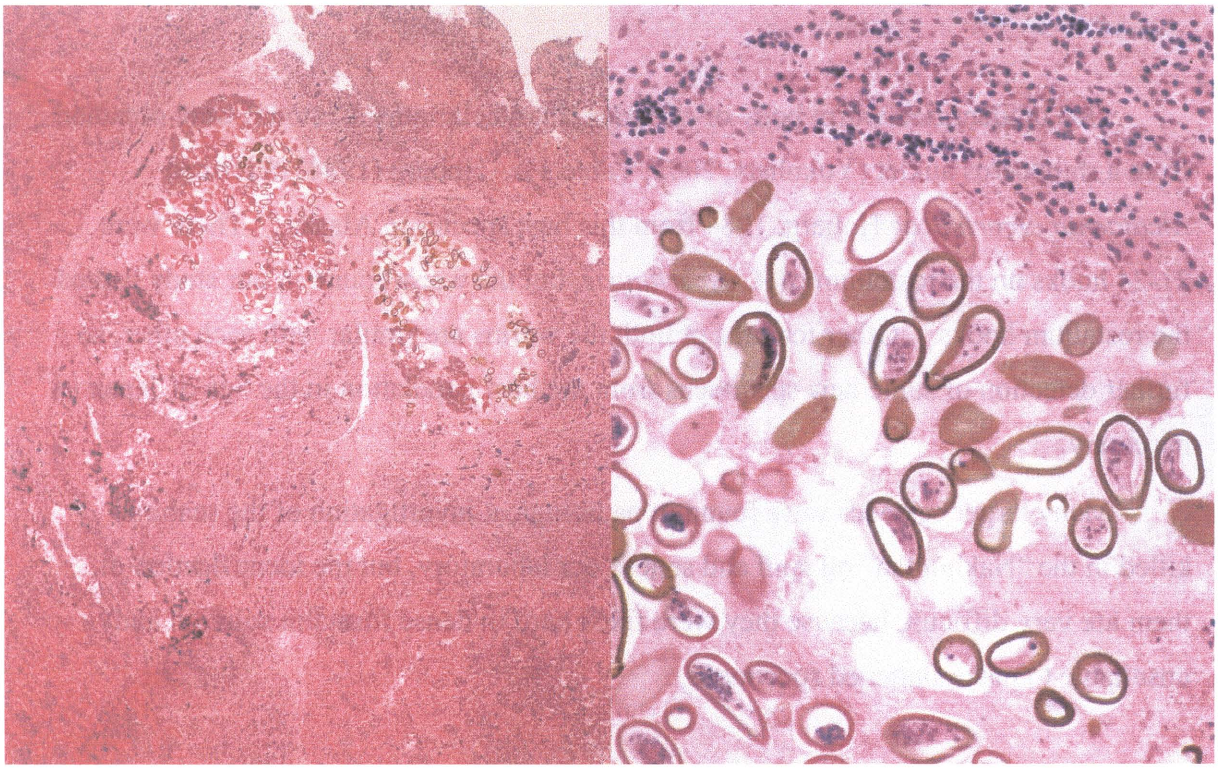

Figure 1 *Renicola* sp. in histopathological sections (H-E stain) of the kidney of an ancient murrelet (*Synthliboramphus antiquus*) killed in the "Nakhodtka" oil spill (right:: eggs in worm body, about 30×20 μ in diameter; courtesy of Dr. T. Masegi).

determine that the present ones belongs to a new species. On the other hand, Asakawa *et al.*(1999) and Matsumoto and Asakawa (2001) found *Aporchis* sp. from rhinoceros auklets and black-tailed gulls (*Larus crassirostoris* Vieillot, 1818) obtained in Rishiri Island, Hokkaido, Japan, so that comparison between the worms of this genus from Ishikawa and Hokkaido Prefectures.

(2) *Renicola* sp.

One trematode species in the genus *Renicola* (Plagiorchiformes: Renicolidae) was recognized in histopathological sections of kidneys of 21 of 50 ancient murrelets and 15 of 50 marbled murrelets (Yokohata, 2002; Table 1). Mature worm bodies of this genus become pouch-like shape, mostly including numerous tanned eggs (Fig. 1), so that the identification in species level is very difficult. At least more than 50 species have ever been described, but their validity is often suspicious (Ching, 1989).

CESTODES

One unidentified worm body of cestodes (Platyhelminths: Cestoda) were obtained from a rhinoceros auklet (Yokohata, 2002; Table 1). Hoberg (1984) described *Alcataenia cerorhincae* Hoberg, 1984 from this host species in Alaska. There were 21-24 hooks on the rostellum of *A. cerorhincae*, but the worm found in our study lacked the rostellum hooks. Other features of both the worms are similar with each other, so further detection of some new specimens from the host population in the Sea of Japan is necessary.

Many larger cestodes were found in pathological investigation of the seabirds killed in the "Nakhodtka" oil spill and sent to our laboratory, but the identification of them are very difficult, because they were fixed hard in dense formalin solution and unsuitable to make flattened specimens.

NEMATODES

Six species of parasitic nematodes (Aschelminths: Nematoda) were obtained from the digestive tracts of five host species in our study (Yokohata, 2002; Table 1).

(1) Spirurid nematodes in gizzards

In our study, three species of suborder Spirurata (Phasmida: Spirurida) were obtained. *Stegophorus stercorarii* Leonov, Sergeeva & Tsimbalyuk, 1966 (family Streptcaridae) and *Paracuaria adunca* (Creplin, 1846) (family Acuariidae) were obtained from five and nine ancient murrelets, respectively. *Streptocara crassicauda* (Creplin, 1829) (family Streptcaridae) was detected from each one rhinoceros auklet and Pacific loon (Yokohata, 2002; Table 1). These birds were parasitized by the spirurid nematodes under the hard lining epithelium of their gizzards (Fig. 2). *S. stercorarii* has ever been found from the Sea of Japan (Barus *et al.*, 1978), but there is no report of this species in any coast of Japan. Machida (1967) reported *Paracuaria macdonaldi* Rao, 1951 (=*P. adunca*) from a herring gull (*Larus argentatus* Pontoppidan, 1763) collected in Hokkaido Island. Matsumoto and Asakawa (2001) reported *Paracuaria tridentata* (Linstow, 1877) (=*P. adunca*) from five black-tailed gulls (*Larus*

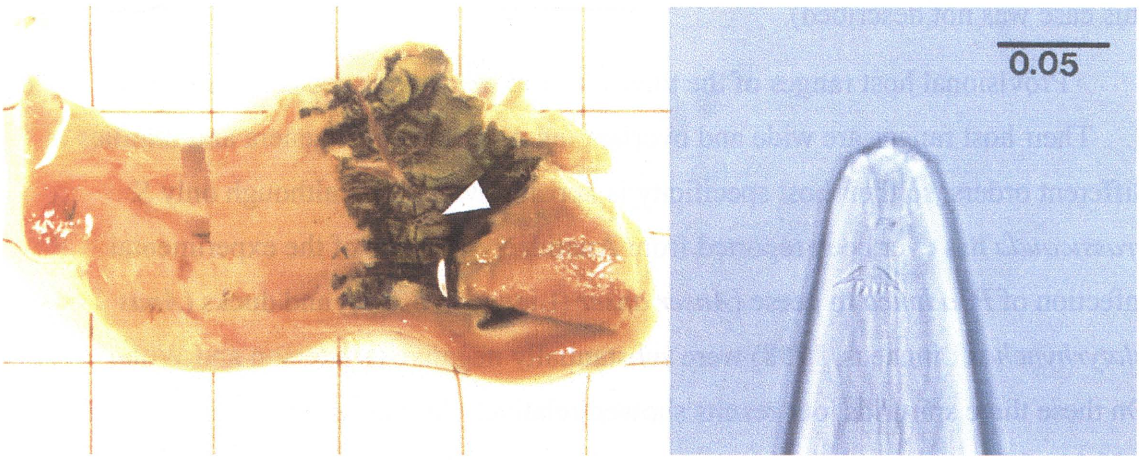

Figure 2 Gizzard nematodes obtained from seabirds killed in the "Nakhodka" oil spill.
Left: A gizzard of an ancient murrelet (*Synthliboramphus antiquus*) with an "8" shaped *Stegophorus stercorarii* (white arrow) (each grid 1 cm in width).
Right: Anterior end of a female *Streptocara crassicauda* obtained from a Pacific loon (*Gavia pacifica*). Cervical pappillae with four to seven denticles (seven in this picture) is characteristic. Bar = 0.05 mm.

crassirostris Vieillot, 1818) collected in Rishiri Island, near Hokkaido Ialand. Yamaguti (1935) has ever reported *Streptocara recta* (Linstow, 1879) (=*S. crassicauda*) which parasitized in a little grebe (*Tachybaptus ruficollis* (Pallas, 1964)) from Lake Biwa. Our findings on these gizzard nematodes were the first records of *S. stercorarii* from the coast of the Sea of Japan in Japan, of *P. adunca* from the coast of the Sea of Japan in Honshu Island and of *S. crassicauda* from the coast of Japan.

In and around the Japan Archipelago, some nematodes related with the three species have been found from various seabirds. Machida (1967) reported *Paracuaria* sp. and *Stegophorus* sp. from a slaty-backed gull (*L. schistisagus* Stejneger 1884) collected in Hokkaido. *Stegophorus stellaeopolaris* (Parona, 1901) has been found from a northern fulmar *Procellaria glacialis* (Linnaeus, 1761) collected in northern waters (Machida and Fukumoto, 1980) and from thick-billed murres (*Uria lomvia* (Linnaeus, 1758)) collected in a coast in Niigata Prefecture (Hasegawa and Ishida, 1980). Nagasawa *et al.* (1998b) reporded *S. stellaeopolaris* from thick-billed murres collected in the Bering Sea. This report reviewed the biology of this nematode species, including the geographic distribution and host range. Recently, Iwaki *et al.* (2001) have also found this nematode species with two cestode species from a short-tailed albatross (*Diomedea albatrus* Pallas, 1769) collected in Japan (the precise locality of this case was not described).

Provisional host ranges of the three spirurid nematode species are shown in Table 3. Their host ranges are wide and overlapping in various host genera and families in different orders, so their host specificity is apparently obscure, although only *S. crassicauda* has ever been reported from Anatidae. Results of the experimental infection of *P. adunca* to geese (*Anser anser* (Linnaeus, 1758)) and ducks (*Anas platyrhynchos* Linnaeus, 1758) were substantially negative (Anderson and Wong, 1982). On these three spirurids, our results showed relatively low prevalence (e.g. 5.26 and 8.33 % of *S. crassicauda* in rhinoceros auklets and Pacific loons, respectively; Table 1), though Anderson and Wong (1982) showed higher prevalence of *P. adunca* in ring-billed gulls (*Larus delawaensis* Ord, 1815) in Ontario, Canada. At least among the present host species, the present low prevalence may suggest mild interspecific competition (isolationist community, in Pence (1990)). Relationships between such feature of the community of these nematodes and the apparent low degree of their host specificity is an interesting subject in future.

Table 3 Provisional host ranges of the three species of spirurid gizzard nematodes

Hosts		Nematodes		
Family	Species	Ss	Pa	Sc
Order Procellariiformes				
Procellaariidae	Northern fulmar *Fulmarus* (=*Procellaria*) *glacialis*	+	+	
	Manx shearwater *Puffinus puffinus*			+
Order Gaviiformes				
Gaviidae	Arctic loon *Gavia arctica*		+	+
	Red-throated loon *G. stellata*		+	+
Order Podicipediformes				
Podicipedidae	Horned grebe *Podiceps auritus*			+
	Great crested grebe *P. cristatus*			+
	Red-necked grebe *P. griseigena*		+	+
	Eared grebe *P. nigricollis*			+
	Little grebe *P.* (= *Tachybaptus*) *ruficollis*		+	
Order Pelecaniformes				
Phalacrocoracidae	Common cormorant *Phalacrocorax carbo*			+
	Pelagic cormorant *P. pelagicus*		+	
	Pygmy cormorant *P. pygmaeus*			+
Order Ciconiiformes				
Ardeidae	Bittern *Botaurus stellaris*		+	+
Order Anseriformes				
Anatidae	Smew *Mergus albellus*			+
	Common mergenser *M. merganser*			+
	Red-breasted merganser *M. serrator*			+
Order Charadriiformes				
Laridae	Long-tailed skua *Stercorarius longicaudus*	+		
	Arctic skua *S. parasiticus*	+	+	
	Pomarine skua *S. pomarinus*	+		
	Ivory gull *Pagophira eburnea*		+	
	Red-legged kittiwake *Rissa brevirostris*		+	
	Black-legged kittiwake *R. tridactyla*		+	+
	Ross' gull *Rhodosthethia rosea*		+	
	Herring gull *Larus argentatus*	+	+	+

Nematodes: Ss: *Stegophorus stercorarii*; Pa: *Paracuaria adunca*; Sc: *Streptocara crassicauda*; Based on Barus (1978) and Wong and Anderson (1982a) *

Table 3 (Continued)

Hosts		Nematodes		
Family	Species	Ss	Pa	Sc
Order Charadriiformes				
Laridae	Common gull *L. canus*			+
	Black-tailed gull *L. crassirostris*		+	
	Ring-billed gull *L. delawarensis*		+*	
	Lesser black-backed gull *L. fuscus*		+	
	Slender-billed gull *L. genei*		+	+
	Glaucous-winged gull *L. glaucescens*		+	
	Glaucus gull *L. hyperboreus*		+	
	Great black-headed gull *L. ichthyaetus*		+	+
	Great black-faced gull *L. marinus*		+	
	Mediterranean gull *L. melanocephalus*		+	
	Little gull *L. minutus*		+	+
	Black-headed gull *L. ridibundus*		+	+
	Slaty-backed gull *L. schistisagus*		+	+
	Gull-billed tern *Gelochelidon nilotica*			+
	White-winged tern *Chlidonias leucoptera*		+	
	Caspian tern *Hydroprogne tschegrava*		+	+
	Little tern *Sterna albifrons*		+	
	Common tern *S. hirundo*	+	+	+
	Sanwich tern *S.* (= *Thalasseus*) *sandvicensis*	+	+	
Alcidae	Crested auklet *Aethia cristatella*	+		
	Least auklet *A. pusilla*	+		
	Whiskered auklet *A. pygmaea*		+	
	Razorbill *Alca torda*			+
	Parakeet auklet *Cyclorrhynchus psittacula*		+	
	Horned puffin *Fratercula corniculata*	+		+
	Tufted puffin *Lunda cirrhata*	+		
	Murre *Uria aalge*			+
	Thick-billed murre *U. lomvia*	+		+
	Black guillemot *Cepphus grylle*	+		

Nematodes: Ss: *Stegophorus stercorarii*; Pa: *Paracuaria adunca*; Sc: *Streptocara crassicauda*; Based on Barus (1978) and Wong and Anderson (1982a) *

On the other hand, in Toyama Bay, central area of the coast in Japan of Sea of Japan, there have been some cases of a human larval spirurid nematode disease caused by eating of raw meat of firefly squids (*Watasenia scintillans* (Berry, 1911)), which is an intermediate or paratenic host of the causal nematode. Its patients often show severe symptons, such as subcutaneous larva migrans and intestinal collapse (Akao *et al.*, 1995). Diffinitive hosts of the causal nematode are unknown, so that the detection of these three spirurids from the seabirds are noticed on the epidemiology of this disease. The pathogenicity of some larval streptcariid and acuariid nematodes including *S. crassicauda* has ever been examined experimentally, and a type of the larvae (species unknown) from a walleye pollack (*Theragra chalcogramma* (Pallas, 1811)) showed migration into the intestinal wall of rabitts (*Oryctolagus cuniculus* (Linnaeus, 1758)) (Hasegawa, 1978). Anderson and Wong (1982) experimentally infected larval *P. adunca* to three species of amphipods, and obtained larvae in infective stage to definitive hosts. Two species of related nematode species, *Echinuria nucinata* (Rudolphi, 1819) and *Cosmocephalus obvelatus* (Creplin, 1825) utilize amphipods and copepods as intermediate hosts, respectively (Austin and Welch, 1972; Wong and Anderson, 1982b). Diets of the firefly squids from the Sea of Japan contain some amphipods and copepods (Hayashi, 1995). The relationships between the adult nematodes from the various seabirds and the larvae from the firefly squids would have to be examined using some methods, such as experimental infection and molecular biological techniques.

(2) *Contoracaecum rudolphii* Hartwich, 1964

This nematode species was the most dominant among the helminths obtained in the present study, and detected from the stomachs and intestines of all five host species (Table 1; Fig. 3). These cases were new host records of this species, except for the ancient murrelet (Barus *et al.*, 1978). It belongs into Anisakidae in Ascaridida, and has so far been reported from many species of seabirds with worldwide distribution (Hartwich, 1964; Barus *et al.*, 1978, 2000) including areas in and around Japan (Yamaguti, 1941; Yamagishi 1997; Asakawa *et al.*, 1999; Yokohata, 2000). Yamaguti (1941) described *C. umiu* Yamaguti 1941 from a Temminck's cormorant in Japan, but probably this species is a junior synonym of *C. rudolphii* (Barus *et al.*, 2000).

Figure 3 *Contracaecum rudolphii* from seabirds killed in the "Nakhodtka" oil spill.
Left: Male (small) and female (large) worms from an ancient murrelet (*Synthliboramphus antiquus*) (each grid 1 cm in width).
Right: Anterior end of a male worm obtained from a Pacific loon (*Gavia pacifica*). Bar = 0.06 mm.

Yamagishi (1997) introduced a case of detection of *C. spiculigerm* (Rudolphi, 1809) (= *C. rudolphii*) from a common cormorant (*Phalacrocorax carbo* Linnaeus, 1758) from Lake Biwa, the largest freshwater lake in Japan. This case shows that the common cormorant in Lake Biwa must forage in marine environment. Asakawa *et al.* (1999) reported this nematode species from a Temminck's cormorant (*Phalacrocorax capillatus* (Temminck et Schlegel , 1850)) obtained in Rishiri Island, Hokkaido.

On the genus *Contracaecum* from Japan, other than this species, *C. yamaguti* Mawson, 1956 was reported from a common merganser (*Mergus merganser* Linnaeus, 1758) in Japan (Barus *et al.*, 1978), but this nematode species is junior synonym of *C. variegatum* (Rudolphi, 1809) (Nagasawa *et al.*, 1998a). Yamaguti (1935) described *C. microcephalum* (Rudolphi, 1809) from a night heron (*Nycticorax nycticorax* (Linnaeus, 1758)) (its locality is unknown, but possibly in Japan) and *C. torquatum* Yamaguti, 1935 (= *C. variegatum*) from common gull (*Larus canus* Linnaeus, 1758) in Kuki, Mie Prefecture, Japan. *C. variegatum* was also reported from thick-billed murres (*Uria lomvia* (Linnaeus, 1758)), a common murre (*U. aalge* (Pontoppidan, 1763)) and tufted puffins (*Lunda cirrhata* (Pallas, 1767)) from Bering Sea, with *Contracaecum* sp. from a common murre from the Sea by Nagasawa *et al.*, (1998a) . Yamaguti (1941) described *C. himeu* Yamaguti, 1941 from a pelagic cormorant (*Phalacrocorax pelagicus* (Pallas, 1811)) . *C. himeu* was also reported from Temminck's cormorants obtained from the

1811)) . *C. himeu* was also reported from Temminck's cormorants obtained from the coast of the Japan Sea in Honshu, Japan (Nagasawa *et al.*, 1999b). This case is based on seabirds killed in the "Nakhodka" oil spill , as same as our study. The validity of *C. himeu* was certified, using scanning electron microscopy (Barus *et al.*, 2000).

(3) Other nematodes

One larva of *Syngamus* sp. (Strongylida; Syngamidae) was obtained from an intestine of a rhinoceros auklet, and two larvae of subfamily Capillarinae (Enoplida; Trichuridae) were detected from a gizzard of a Pacific loon (Table 1). These nematode taxa have been known from fish-eating birds of the Palaearctic Region (Barus *et al.*, 1978) but identification of these larvae on specific level is difficult.

CONCLUDING REMARKS

Among the five bird species researched in the present study, marbled murrelets and red-necked grebes harbored only *C. rudolphii*, which is the most dominant species of the helminths obtained in the present study. The prevalence of this nematode species in the red-necked grebes was much lower than those in the other host species (Table 1). We examined only two marbled murrelets, but we did 15 red-necked grebes, so that simplicity of gastrointestinal parasitic helminth community of the latter host species is obvious. Mosts of grebe species live in freshwater environment, and more than ten species of parasitic helminths have been detected in studies of their parasitic helminth communities (Stock and Holmes, 1987 1988), so that the parasitic helminth communities of grebes in freshwater environment are not as simple as the present case of red-necked grebes.

This simplicity might be attributable to migration of this bird species. The red-necked grebes live in sea in winter, but do in freshwater lakes, so that such extreme environmental change might prevent the establishment and persistence of life cycles of the parasitic helminths with short longevity. If the helminths infected in summer or winter in freshwater or marine environment laid their eggs in winter or summer respectively, their larvae would encounter no suitable condition and no available intermediate hosts.

However, many parasitic helminths of hosts in habitats with severe seasonal environmental changes often acquire some adaptive features, such as arrested development (e.g. Belem *et al.*, 1993) to overcome the extreme seasonal changes. Further, the Pacific loons, which were investigated of about equal number as the grebe species in the present study, often live in the freshwater environment as same as the grebes, but the loons harbored three species of helminths. Moreover, among the helminth species obtained in the present study, *P. adunca* is certified to infect to young-of-the-year ring-billed gulls and to develop fast to mature 16-18 days postinfection in the young gulls (Anderson and Wong, 1982).

Another difference between the grebes and the other seabird species is on the length of history of habituation in and adaptation to the marine habitat. On Gaviiformes, including the loons, fossils are known since in Eocene in Tertiary Period, and on Charadriiformes, including the murrelets and rhinoceros auklets, those are found since in Cretaceous Period (Caroll, 1988). Some avian higher taxa adapting marine environment, such as these two orders, are assumed to be with long history of marine adaptation attaining to some dozen million years. In contrast, some marine grebes including the red-necked grebes are with much shorter history of marine adaptation after divergence from their ancestors living in freshwater habitats. It might be difficult for the helminths to adapt marine environment in the short evolutional history. High species diversity of some biological communities are often attributable to their long history (e.g. myrmecophiles Aoki, 1973; tropical rain forest: Pianka, 1980; parasitic hemipterans: Tallamy, 1983). On the present case of parasitic helminth community of the red-necked-grebes, it is supposed that the shortness of histories of marine adaptation of both the hosts and parasites limits the diversity of parasite communities. I will conduct further investigation on the rest seabird species, to make this hypothesis more persuasive.

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